GDP-0007

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KY/L-1239

PGDP

PADUCAH GASEOUS DIFFUSION PLANT

MARTIN MARIETTA

HISTORICAL IMPACT OF REACTOR TAILS ON THE PADUCAH CASCADE

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CLASSIFICATION CHANGED TO Unclassified
BY AUTHORITY OF R. L. Harris
BY C. A. Hudson (person changing document markings) DATE 11-24-87

March 1984

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

CLASSIFICATION OR RECLASSIFICATION

TITLE OR DESCRIPTION: HISTORICAL IMPACT OF REACTOR TAILS ON THE PADUCAH CASCADE

DOCUMENT NUMBER: KY/L-1239

DOCUMENT DATE: 3-19-84

AUTHOR(S) AND ORGANIZATION: R.F. SMITH TECHNICAL SERVICES

CATEGORY: ☐ ADMIN. ☒ SCIENT. & TECH.

NO. OF PAGES: 57

TYPE OF DOCUMENT: ☒ REPORT ☐ MEMO ☐ PHOTO ☐ LETTER ☐ DRAWING ☐ OTHER

COPIES RE-MARKED:

FORMER CLASSIFICATION: C-RD

NEW CLASSIFICATION: UNCLASSIFIED

APPLICABLE GUIDE REFERENCE: CG-PGD-4 (ATTACH CAUTION NOTICE)

CERTIFIED BY: PLANT: PGDP DATE:

AUTHORIZED BY: R L Harvey DATE: 11-24-87

UCN-3657 (1235 .11-82)

DISCLAIMER

ABSTRACT

A knowledge of cascade history relative to reactor tails has been useful in answering many questions which have arisen over the years and continue to arise. This report contains a comprehensive summary of historical data which should be useful in answering such questions in the future.

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INTRODUCTION

A knowledge of cascade history relative to reactor tails feeds has been useful in answering a substantial percentage of questions referred to the Analytical Services Lab by various PGDP and other Nuclear Division groups. Questions continue to arise concerning concentrations of radiochemical impurities and minor isotopes in PGDP feed, product, and tails. Much of the historical data has been published in voluminous classified reports; however, production reactor tails information has since been declassified. Presented here is a comprehensive unclassified summary of reactor tails feeds to the PGDP cascade from startup (FY-53) through the last year such material was fed (FY-76). Data relative to destination of minor isotopes and radiochemical impurities are included. It is hoped that this summary will be useful in answering future questions concerning the cascade.

DOMESTIC REACTOR TAILS RECEIVED AND FED AT ENRICHMENT PLANTS

Appendix 1 summarizes feeds to and withdrawals from the PGDP cascade from startup (FY-53) through FY-76. Depleted reactor tails were fed to the cascade from FY-53 through FY-64. That feed was again reinstated in FY-69 and continued through FY-74 except for FY-71 when none of the feed was of reactor origin. Enriched reactor tails received from Hanford were fed to the cascade during only three FY's, those being 73, 75, and 76 (Actually was fed from April through June 1973, and June 1 through September 11, 1975). No reactor tails, depleted or enriched, have been fed to the Paducah cascade since September 11, 1975. We still have in the yard for future feeding 335 MTU of depleted reactor tails at an average assay of 0.633 wt. % ^{235}U. We received more enriched reactor tails than was fed; however, the remaining material was never converted to UF_6 and is being shipped to NLO as UO_3. The material being shipped to NLO has an assay greater than 0.80 wt% ^{235}U.

Appendix 1 can be used in making ball park judgments concerning the cascade for any of the 24 years from startup through FY-76. Although the history of PDF and SHAFT feeds are not precisely known, they have little effect on anything but ^{236}U since impurities preferentially move up stream. It will be observed from Appendix 2 that approximately 65% of the PGDP cascade feed for FY-73 was reactor tails. That is by far the highest percentage for any year. Periods with the next greatest percentage were FY-57 and FY-70 with about 35% each. Although percentage of reactor tails feed was relatively small, the period between June 1 and September 11, 1975 is of interest since ERT contained higher concentrations of Tc and ^{236}U.

Appendix 3 gives a detailed summary of all production reactor tails fed to enrichment cascades through FY-74. Not included is 1373 tons ERT fed to the PGDP cascade between June 1 and September 11, 1975 (415 tons in FY-75 and 958 tons in FY-76). It will be observed that over 94% of all production reactor tails were fed at Paducah with less than 0.5% being fed at GAT.

Some foreign reactor tails, chiefly French and English (BNFL), have been received and fed at ORGDP. An average of 20 cylinders per year has been received by them since 1969, with the range being 0 to 53 cylinders per calendar year.

Appendix 4 compares total quantities of reactor tails and normal fed to the three enrichment plants through FY-74. Other feeds for the period were recycle material; PDF, SHAFT, and ORGDP or PGDP product.

Appendix 5 summarizes total feeds and productions at Paducah through FY-76 (24 years). It will be observed that recycle (PDF and SHAFT), normal (natural), and reactor tails feeds constituted approximately 69%, 17%, and 13%, respectively. Production was about 82% tails, 16.5% product and 1.5% special side withdrawal.

Appendix 6 summarizes the enrichment plant tails stockpile as of June 30, 1975, while Appendix 7 gives net enrichment plant tails through June 30, 1975. It is obvious that most tails produced through that time had been refed as PDF or SHAFT. Shipments and discards listed in Appendix 7 were from Paducah, chiefly as UF_4 and U metal.

CONTENT OF SUBSTANCES PECULIAR TO REACTOR TAILS

MINOR ISOTOPES

Appendix 8 compares calculated ^{236}U production in reactors with analytical measurements, and good agreement is shown for material received prior to 1967. Material processed after recycling started contained more ^{236}U as expected; however, calculations are not possible without complete history. Measurements indicated that reactor tails received after 1967 contained an average of about 20% more ^{236}U than that received earlier (eg: 133 instead of 110 ppm for HRT and 204 instead of 170 ppm for SRT). All enriched reactor tails have been recycled, so there is no way of calculating ^{236}U concentration. Six measurements performed (3 on UF_6 fed to the cascade and 3 on UO_3 sent to NLO) gave a ^{236}U average of 473 ppm (0.0473 wt. %) with a range of 270 to 680 ppm.

Unlike ^{236}U which is of reactor origin, ^{234}U tends to enrich and deplete in proportion to ^{235}U as UF_6 moves through the cascade. Thus, ^{234}U doesn't vary greatly for any specific ^{235}U concentration; however, feed distribution can produce some ^{234}U variability which is difficult to visually detect over the Paducah isotopic range. A high proportion of PDF or SHAFT feed tends to reduce the ^{234}U gradient relative to ^{235}U since ^{234}U has been preferentially depleted in such material. A high proportion of reactor tails feed tends to enhance the ^{234}U gradient relative to ^{235}U since ^{235}U in such material has been depleted while ^{234}U remained relatively unchanged.

TECHNETIUM-99

In November 1973, I gave Alice Story a ^{99}Tc estimate of 7 ppm ±30% (U basis) for all depleted reactor tails received at Paducah. Hundreds of measurements had been performed from 1959 up to that time and essentially all of them clustered in a range of 4 to 10 ppm on a U basis. That is still the best ^{99}Tc concentration estimate for all HRT and SRT uranium received through FY-74. Only five measurements were performed on ERT, two on material fed to the cascade and three on material shipped to NLO, and the average concentration was 16 ppm on a U basis which is the best estimate for that material. Appendix 9 summarizes HRT, SRT, and ERT uranium fed to the Paducah cascade and estimates the ^{99}Tc received in it. Based on Tc balance data accumulated prior to December 1973, Alice Story estimated that about 95% of Tc entering the feed plant with UO_3 is withdrawn in the UF_6 product, and about 90% of that in feed plant product cylinders is vaporized to the cascade giving a net cascade feed percentage of about 85. As seen in Appendix 9 an estimated 539 kg of Tc was fed to the cascade after correcting the net cascade feed percentage for approximately 27 kg of Tc trapped in C-410 MgF_2 traps.

NEPTUNIUM-237

Neptunium concentration of reactor tails uranium is summarized in Appendix 10. Measurements were not made on material received prior to FY-57 and most measurements performed after that were on monthly composite samples of UO_3 received. Complete analyses were not performed on any stream, and measurements on some were more fragmentary than others. Even so, Appendix 10 gives the best estimate for the quantity of ^{237}Np received in reactor tails fed at Paducah. Between 10% and 40% of ^{237}Np received entered the cascade with UF_6 according to estimates made by W. R. Golliher and associates. Using an estimate of 25%, approximately 4.6 kg of ^{237}Np was fed to the Paducah cascade.

PLUTONIUM-239 (INCLUDES PLUTONIUM-240 CALCULATED AS PLUTONIUM-239)

Plutonium concentrations of reactor tails uranium is summarized in Appendix 11. Measurements were made starting in FY-54; however, analyses were biased high for material received prior to 1967. Up to that time, pulse height analyses were not performed to correct measurements for alpha emitting impurities (chiefly Np); so, the 4 ppb average constitutes an upper limit for ^{239}Pu. Most Pu received was deposited in Feed Plant ash receivers, and very little accompanied UF_6 into the cascade. Cascade dusts near reactor tails feed points were analyzed for Np and Pu in 1966. Since Np is known to be more mobile in the cascade than Pu, the relative ratio of Np and Pu alpha activity should have given a conservative upper limit for Pu fed. Those measurements showed ^{239}Pu activity to average <0.2% of the ^{237}Np activity. Extrapolating on the assumption that 4.1 kg. Np had been fed to the cascade up to that time, less than 0.1 gram of Pu would be indicated. Plutonium fed after 1967 was <20% of that fed previously, so 0.1 gram is the best estimate of ^{239}Pu fed to the cascade.

FISSION PRODUCT BETA AND GAMMA

A nuclear power reactor fueled with ^{235}U produces fission products at more than 80 different mass numbers which further decay to produce a total of more than 260 radioactive species. Most of the radioactive nuclides have short half lives, and decay to negligible concentrations in a matter of a few months. A few have long half lives and/or low yield resulting in negligible radioactivity. Considering half life, fission yield, and radioactive emission, seven species would be expected to produce a predominance of fission product gamma radioactivity after a period of 4 to 6 months aging; those being ^{95}Zr-Nb, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{141}Ce, and ^{144}Ce. In the mid-seventies, I devised a procedure for measuring those seven species as a substitute for the antiquated gamma specification measurement which was based on using a high pressure gamma chamber to compare fission product gamma to that of aged natural U. The new procedure which permits modern pulse height analyzer instrumentation to measure fission product gamma has been proposed to DOE. In the processing of spent reactor fuel, transuranic elements and fission products are preferentially separated from uranium, further reducing fission product radioactivity; however, decontamination factors differ for the various species.

At least four of the seven expected gamma emitting fission products were identified by ORNL in Paducah Feed Plant ash during the 1957-1958 period; those being ^{95}Zr-Nb, ^{106}Ru, ^{137}Cs, and ^{144}Ce. They identified the same four

species in 1963 Feed Plant ash and failed to detect ^{125}Sb. In the mid sixties, the Paducah Lab identified fission product gamma energies in reactor return UO_3 which could account for part or all of the following nuclides; ^{103}Ru, ^{106}Ru, ^{137}Cs, ^{141}Ce, and ^{144}Ce. Thus, it is possible that six of the seven gamma emitters have been indicated in reactor return UO_3 or Paducah Feed Plant ash. ^{125}Sb has not been indicated, and I am not aware of a positive identification for ^{103}Ru and ^{141}Ce. Most reactor returns were processed at Paducah before sophisticated instrumentation was available to identify specific radioactive nuclides, so trace concentrations of unidentified species were possible. I once saw a report draft that quoted the following fission product gamma distribution for typical reactor return material, but I am not privileged to the source of the data.

Radioactive Nuclide	% of Total Fission Product Gamma
^{106}Ru	75
^{95}Zr-Nb	22
^{137}Cs	1
^{144}Ce	1
All others	1

Although there are about a half dozen pure or essentially pure beta emitting fission products with adequate half life and fission yield to survive 4 to 6 months aging, most of them apparently have relatively large decontamination factors in the uranium recovery process. Technetium is a notable exception since it was received in the greatest concentration of any fission product; however, it has been discussed separately. One other pure beta emitter, ^{90}Sr, was possibly received in trace concentrations. A few ORNL measurements in 1957 indicated positive concentrations of Sr in Paducah Feed Plant ash while similar measurements in 1958 indicated Sr concentrations to be below the detectability level. In 1963, ORNL detected Sr in Paducah Feed Plant ash but not in reactor return UO_3. If other pure beta emitters were received, they were not identified.

In summary, we received large quantities of ^{99}Tc in reactor return uranium material. Four gamma emitting fission products were positively identified in Paducah Feed Plant ash; those being, ^{95}Zr-Nb, ^{106}Ru, ^{137}Cs, and ^{144}Ce. There are indications that ^{90}Sr, ^{103}Ru, and ^{141}Ce were received. Except for Tc, only trace quantities of fission products were received in reactor return UO_3. Total fission product gamma was consistently less than 10% the gamma activity of aged natural uranium.

FOREIGN REACTOR TAILS RECEIVED AT ORGDP

As mentioned earlier, an average of 20 cylinders per year of foreign reactor returns has been received at ORGDP since 1969. At least a few of the cylinders, designated as "Russian" by the intermediate supplier, had apparently never been in a reactor. Most of the foreign reactor returns came from England (BNFL) or France, with France providing the predominance of the material. France supplied all the cylinders received in the past two years (61 cylinders total for CY-81 and CY-82).

Cylinders were 2-1/2 ton capacity, so ORGDP has been receiving an average of about 34 tons reactor return uranium per year. Total for 14 years is about 470 tons.

Appendix 12 summarizes isotopic and radiochemical measurements on French reactor returns for CY-82. None of the foreign reactor returns has exceeded radiochemical specifications since 1973, and isotopic specifications have never been exceeded. Other specifications have been exceeded on only four cylinders of foreign reactor returns since 1973, and all those were French cylinders received in 1982 which failed to meet the Mo specification. Federal Register Specifications have not been exceeded by any foreign reactor returns except those from France. During the period CY-69 through CY-73, ten French reactor return cylinders failed to meet specifications; six for transuranic alpha, one for fission product beta and gamma, and three for elemental Mo.

The transuranic alpha measurement is derived from neptunium and plutonium analyses. Over the past two years, the Pu has ranged from <0.01 to about 0.04 ppb on a uranium basis while the Np has ranged from <3 to 10 ppb.

DISTRIBUTION OF MINOR ISOTOPES AND RADIOCHEMICAL IMPURITIES IN PGDP CASCADE

MINOR ISOTOPES

Measurements have been made for minor isotopes in PGDP tails and product at random intervals since 1955, and data is summarized in Appendix 13. Unfortunately, no measurements were made for the period June 1973 through July 1976. Gaps between successive measurements are relatively brief for the remainder of the time period October 1955 through December 1982.

For the measurements made, ^{236}U in nominal 0.2 wt. % tails attained a maximum of 0.0045 wt. % in December 1969. For nominal 0.3 wt. % tails, the

maximum measured was 0.0092 wt. % in December 1972. The highest ^{236}U measured in PGDP product was 0.0701 wt. % on a cylinder withdrawn May 21, 1973 which had a ^{235}U enrichment of 1.6 wt. %.

As expected, the ^{234}U assay range for specific ^{235}U enrichments was relatively small. For example, ^{234}U in nominal 0.2 wt. % tails ranged from 0.0006 to 0.0010 wt. %. For nominal 0.3 wt. % tails, ^{234}U ranged from 0.0012 to 0.0018 wt. %. The highest ^{234}U measured in product was 0.0172 wt. % obtained in June 1978 when product enrichment was at a nominal 1.95 wt. % level.

Maximum ^{236}U enrichments in PGDP product have been estimated by comparing available measurements to cascade feeds (Appendices 2 and 13). Reactor tails constituted a far greater fraction (~65%) of feed to the PGDP cascade in FY-73 than for any other year, and a portion of that feed for the last quarter was ERT which had a much higher ^{236}U enrichment than depleted reactor tails. Four minor isotope measurements were made on FY-73 PGDP product, and all were higher than any measurement performed in another year. A ^{236}U enrichment of 0.0292 wt. % on 1.7 wt. % product was obtained at the end of December 1972 when reactor tails constituted about 85% of the cascade feed but before ERT feed was introduced. The highest enrichments measured were for May 1973 when ERT constituted about 52% of the feed and combined reactor tails accounted for about 93%. Average ^{236}U enrichment of three cylinders withdrawn that month was 0.0625 wt% (0.0701, 0.0608, and 0.0565).

Estimates have been scrutinized to determine the maximum ^{236}U enrichment contributed to reactor grade UF_6 (3 wt. % ^{235}U) by the ^{236}U in PGDP product. Enrichments in the order of 0.1 wt. % ^{236}U would be expected if cylinders produced in the last quarter of FY-73 were fed undiluted to an upper cascade. Product from all other periods would be expected to produce reactor grade UF_6 with ^{236}U enrichments less than 0.05 wt. %; however, higher concentrations cannot be completely ruled out for the period June 1 through September 11, 1975 when ERT constituted a relatively small percentage of PGDP feed.

TECHNETIUM-99

Measurements for Tc in cascade tails were not made on material withdrawn prior to June 1973 when I asked that two tails cylinders be field sampled specifically for measuring radiochemical impurities. Reactor tails constituted approximately 65% of the total feed to the cascade in FY-73 and about 27% for the preceding year. For the month in which the two tails cylinders were withdrawn, over 96% of the feed to the cascade was reactor tails.

Measurements for Tc indicated the concentration to be <1 ppb for both cylinders. A cascade product cylinder sampled the same month contained 20 ppm Tc, the highest concentration ever measured on that stream. At least 35 additional tails cylinders were analyzed for Tc for the period FY-75 through FY-82, and all measurements were below the detectability level (1, 5, and 10 ppb detectability levels were used during the period). Thus, there is no reason to assume that any Tc went with the PGDP tails stream.

A MgF_2 trap was installed in C-310 to reduce Tc concentration in cascade product, and started operating January 28, 1963. ORGDP made Tc measurements on PGDP product for the five months preceding the installation, and the concentration average was 3.2 ppm. They continued measurements for four months following installation during which time the average dropped to 0.15 ppm. The trap was dumped about four months after installation, and 5.0 kgs Tc was contained in the MgF_2. The second trap bed was dumped 5.5 months following the first and contained 6.4 kg Tc. At some later date, dumping the MgF_2 trap beds became lax, saturation resulted, and Tc again increased in cascade product. Unfortunately, there were no Tc measurements on cascade product from 1963 till FY-72; however no reactor tails were fed for the period FY-65 through FY-68 nor for FY-71.

Routine Tc measurements on cascade product were not started until FY-72. Measurements since that time are summarized in Appendix 14. It will be observed that the Tc concentration peaked at an average of about 6 ppm in FY-74 and declined from that point on. In FY-82 for the first time the Tc concentration in PGDP product averaged below the detectability level of 0.01 ppm.

No attempt is made here to establish a material balance for Tc entering the cascade. It is known that substantial quantities were shipped out in PGDP product, trapped in MgF_2, and removed with cascade equipment during the two improvement programs. Also, some Tc was vented out the C-310 stack.

NEPTUNIUM-237

Measurements for Np in cascade tails were not performed until two June 1973 cylinders described in the previous section were subsampled for radiochemical analyses. Measurements indicated Np concentration to be <1 ppb on both those cylinders. At least 38 additional tails cylinders were analyzed for Np during the period FY-75 through FY-82, and all measurements were below the detectability level (1 and 5 ppb detectability levels were used). Thus, there is no reason to assume that any Np went with the PGDP tails stream.

Three PGDP product cylinders withdrawn in May 1973 were the first to be analyzed for Np, and 59 additional product cylinders were analyzed over the period FY-76 through FY-82. A few cylinders in the FY-76A-77 period exceeded the 5 ppb detectability level, and one of the 10 cylinders in FY-80 exceeded the 1 ppb detectability level being used that year. The highest concentration measured was 27 ppb in a cylinder from the FY-76A-77 period.

There were earlier indications that traces of Np were entering the product stream. Three MgF_2 trap beds dumped in the 1964 to 1966 period contained an average of 1.9 ppm Np after being leached, while the leach solution contained 0.38 ppm. By way of comparison, average Tc concentrations for the three trap beds were 9000 ppm in the leach solution and 2266 ppm in the leached MgF_2 pellets.

In summary, it is known that a small quantity of Np was trapped in C-310 MgF_2 beds during the mid sixties. Some product cylinders withdrawn in the FY-76A-77 period contained Np at a level above the 5 ppb detectability level, with the highest concentration measured in any cylinder being 27 ppb. Thus, it is concluded that some product UF_6 produced at the PGDP contained traces of Np.

Most Np which entered the cascade was probably removed with cascade equipment during the two improvement programs. Small quantities were shipped out with PGDP product and collected on MgF_2 trap beds. Also, it is likely that traces were vented out the C-310 stack to the environment.

PLUTONIUM-239 (INCLUDES PLUTONIUM-240 CALCULATED AS PLUTONIUM-239)

Measurements for Pu in cascade tails were not performed till 1964 when the Italians claimed U metal fabricated from PGDP tails contained 1.5 ppm Pu. Analyses were made at that time to assure the material shipped to them contained <0.01 ppm Pu, and the Italians eventually agreed that they were in error. Low detectability limit measurements were not performed on PGDP tails withdrawn prior to June 1973 when two cylinders referred to in the previous sections were analyzed for radiochemical impurities. Both cylinders contained <0.01 ppb Pu. Precise measurements have routinely been made on PGDP tails since 1975, and the detectability limit of 0.01 ppb has not been exceeded. Thus, it is concluded that no Pu has been withdrawn in PGDP tails.

Three PGDP product cylinders withdrawn in May 1973 were the first to be analyzed for Pu, and cylinders were analyzed each year from FY-76 through

FY-82. Of 60 measurements made, only two cylinders gave positive concentrations, those being 0.02 and 0.06 ppb. Thus, it is possible, but by no means conclusive, that traces of Pu fed to the cascade were withdrawn in product. At the levels observed, contamination in one of the laboratory preparation steps is always a possibility. The 0.06 ppb measurement was obtained in the FY-76A-77 period when the detectability level was 0.05 ppb while the 0.02 ppb measurement was obtained in FY-80 when the detectability level was 0.01 ppb.

I have estimated that only about 0.1 gram Pu entered the PGDP cascade. Most of that was undoubtedly removed with cascade equipment during the two improvement programs. It is possible, but not probable, that traces of Pu entered the PGDP product stream.

FISSION PRODUCT BETA AND GAMMA

Only two fission products have been identified in the PGDP cascade. Discussed earlier was ^{99}Tc which moved slowly from feed points up the cascade to C-310. Trace concentrations of ^{137}Cs have been identified in cascade dusts. It is possible that traces of the shorter half life fission products (^{95}Zr-Nb, Ru, and Ce) could have been detected in cascade dusts if sophisticated instrumentation had been available during the period when most reactor tails were being fed to the cascade.

CONCLUSIONS

The overall average ^{236}U concentration of 101,268 tons reactor tails U fed to the Paducah cascade from startup through FY-76 was about 126 ppm (0.0126 wt. %). Measurements for ^{236}U in nominal 0.2 wt % PGDP tails have ranged from essentially zero when no reactor tails was being fed to a maximum of 0.0045 wt. %. Measurements on product have ranged from essentially zero to 0.0701 wt. % which was at a 1.6 wt. % ^{235}U enrichment. Reactor tails feeding history and ^{236}U measurements for 24 years indicate that the predominance of PGDP product could have been enriched, undiluted, to reactor grade UF_6 (3 wt. % ^{235}U) without attaining 0.05 wt. % ^{236}U. A notable exception is PGDP product produced in the last quarter (April through June) of FY-73, which contributed about 0.1 wt. % ^{236}U to reactor grade UF_6. A possible exception is product from the period June 1 through September 11, 1975; however, it is estimated that ^{236}U concentration contributed by it was well below the 0.1 wt. % level.

It is estimated that 534 kg, 4.6 kg, and 0.1 gram, respectively, of Tc, Np, and Pu have been fed into the PGDP cascade. There is no indication that any of these substances ever entered the PGDP tails stream. Substantial quantities of Tc entered the product stream as did trace quantities of Np. The predominance of Pu apparently didn't migrate extensively from feed points.

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APPENDIX 1

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds			Withdrawals	
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-53			
PDF	6029	0.40 to 0.65	Tails	7609	0.39 to 0.82
ORGDP SHAFT	1462	0.43 to 0.72	Prod.	1440	0.87 to 1.04
HRT	1565	0.66	Misc.	3	
Misc.	96	0.71			
	9152			9052	
		FY-54			
PDF	16588	0.38 to 0.68	Tails	20679	0.29 to 0.51
ORGDP SHAFT	3869	0.43 to 1.02	Product	3941	0.98 to 1.53
HRT	4104	0.67	Misc.	9	
Misc.	218	0.69 to 1.44			
	24779			24629	
		FY-55			
PDF	40070	0.25 to 0.80	Tails	44101	0.20 to 0.32
ORGDP SHAFT	3964	0.37 to 0.80	Product	4104	0.88 to 1.31
GAT SHAFT	1619	0.37 to 0.80	Special	1459	0.695 to 0.715
HRT	4066	0.66	Misc.	19	
Misc.	116	0.40 to 0.73			
	49835			49683	
		FY-56			
PDF	50039	0.17 to 0.33	Tails	56942	0.16 to 0.20
ORGDP SHAFT	4819	0.20 to 0.67	Product	8096	0.70 to 1.00
GAT SHAFT	2954	0.18 to 0.24	Special	427	0.71
HRT	7383	0.67	Misc.	23	
UK SHAFT	95	0.39 to 0.42			
FPN	140	0.708			
Misc.	54	0.29 to 1.05			
	65484			65488	

APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds		Withdrawals		
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-57			
PDF	3632	0.18 to 0.33	Tails	9585	0.17
ORGDP SHAFT	4984	0.29 to 0.40	Tails	7889	0.23
GAT SHAFT	4871	0.29 to 0.40	Product	9968	0.85 to 1.11
HRT	9674	0.66	Special	204	0.95
UK SHAFT	598	0.39 to 0.43	Misc.	11	
FPN	3051	0.709 to 0.712			
Misc.	859	0.29 to 1.02			
	27669			27657	
		FY-58			
PDF	3514	0.27 to 0.33	Tails	22769	0.28 to 0.42
ORGDP SHAFT	5328	0.38 to 0.42	Product	7425	1.10 to 1.32
GAT SHAFT	5238	0.38 to 0.41	Special	534	0.95
HRT	7653	0.65	Misc.	8	
UK SHAFT	409	0.38 to 0.44			
FPN	8502	0.693 to 0.712			
Misc.	38	0.37 to 1.34			
	30682			30736	
		FY-59			
PDF	9205	0.14 to 0.35	Tails	33034	0.30 to 0.34
ORGDP SHAFT	5666	0.39 to 0.42	Product	7014	1.38 to 1.42
GAT SHAFT	5490	0.38 to 0.41	Special	1143	0.95
HRT	6193	0.65	Misc.	9	
FPN	14364	0.696 to 0738			
TEN	230	0.71			
Misc.	38	0.84 to 1.40			
	41186			41200	

APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds		Withdrawals		
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-60			
PDF	4761	0.35	Tails	29745	0.34
ORGDP SHAFT	6271	0.40 to 0.50	Product	6452	1.40 to 1.60
GAT SHAFT	5926	0.40 to 0.41	Special	1223	0.95
HRT	6292	0.64	Misc.	20	
SRT	25	0.60			
FPN	10211	0.696 to 0.707			
TEN	3928	0.711			
Misc.	41	0.60 to 1.52			
	37455			37440	
		FY-61			
PDF	8622	0.35 to 0.43	Tails	34507	0.34
ORGDP SHAFT	6409	0.39 to 0.43	Product	6428	1.45 to 1.63
GAT SHAFT	6245	0.39 to 0.42	Special	904	0.95
HRT	6205	0.64	Special	6	1.2
SRT	12	0.60	Misc.	8	
FPN	9466	0.697 to 0.710			
TEN	4892	0.711			
Misc.	8	0.59 to 1.60			
	41859			41853	
		FY-62			
PDF	16808	0.36	Tails	40449	0.34
ORGDP SHAFT	6065	0.39 to 0.51	Product	6257	1.38 to 1.62
GAT SHAFT	6148	0.39 to 0.42	Special	282	0.95
HRT	6713	0.63	Special	399	1.2
SRT	265	0.60	Misc.	7	
FPN	6692	0.711			
TEN	4676	0.711			
Misc.	3	0.77 to 1.62			
	47370			37394	

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APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds		Withdrawals		
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-63			
PDF	55578	0.34	Tails	71738	0.30 to 0.31
ORGDP SHAFT	5509	0.38 to 0.42	Product	6361	1.19 to 1.41
GAT SHAFT	4508	0.36 to 0.40	Special	1172	0.95
HRT	7293	0.64	Special	7	1.20
SRT	452	0.60	Special	419	1.24
FPN	2311	0.709	Misc.	6	
TEN	4058	0.711			
Misc.	1	1.24 to 1.41			
	79710			79703	
		FY-64			
PDF	55779	0.30 to 0.32	Tails	67679	0.29 to 0.30
ORGDP SHAFT	4102	0.37 to 0.40	Product	4834	1.25
GAT SHAFT	3556	0.30 to 0.33	Special	1991	0.95
HRT	6025	0.63	Special	559	1.25
SRT	978	0.60	Misc.	1	
FPN	711	0.70 to 0.71			
TEN	3848	0.711			
Misc.	1	0.84			
	75000			75064	
		FY-65			
PDF	24610	0.32	Tails	20690	0.20
Misc.	1	0.86	Product	3851	0.95 to 1.22
			Special	69	0.95
			Misc.	3	0.30 to 0.50
	24611			24613	
		FY-66			
PDF	25334	0.20 to 0.31	Tails	21572	0.20
			Product	3704	0.95
			Special	106	0.95
	25334			25382	

APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds		Withdrawals		
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-67			
PDF	21244	0.30	Tails	18312	0.20
Misc.	7	0.96	Product	2934	0.96
	21251			21246	
		FY-68			
PDF	26560	0.27 to 0.30	Tails	23796	0.20
Misc.	7	0.96	Product	2762	0.96
	26567			26558	
		FY-69			
PDF	7106	0.20 to 0.33	Tails	12234	0.20
ORGDP SHAFT	2463	0.26 to 0.52	Product	6022	0.98
GAT SHAFT	2654	0.24 to 0.51	Misc.	2	
HRT	4781	0.64			
FPN	538	0.708 to 0.712			
TEN	700	0.711			
Misc.	13	0.21			
	18255			18258	
		FY-70			
PDF	50	0.20	Tails	7678	0.20
ORGDP SHAFT	4463	0.39 to 0.52	Product	5438	0.90 to 0.97
GAT SHAFT	3618	0.38 to 0.50			
HRT	4518	0.64			
SRT	11	0.59			
TEN	412	0.711			
	13072			13116	

APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

	Feeds		Withdrawals		
Source	Quantity Tons U	Assay Wt. % ^{235}U	Type	Quantity Tons U	Assay Wt. % ^{235}U
		FY-71			
PDF	56	0.20	Tails	7789	0.20
ORGDP SHAFT	4958	0.19 to 0.53	Product	6144	0.89 to 1.05
GAT SHAFT	4526	0.46 to 0.52	Misc.	2	
TEN	4354	0.711			
Misc.	1	0.705			
	13895			13935	
		FY-72			
ORGDP SHAFT	6062	0.46 to 0.60	Tails	6	0.20
GAT SHAFT	3010	0.34 to 0.51	Tails	13316	0.30
HRT	5283	0.64 to 0.65	Product	5917	0.90 to 1.40
TEN	4918	0.711	Misc.	4	
	19273			19243	
		FY-73			
ORGDP SHAFT	844	0.59 to 0.62	Tails	11256	0.30
HRT	7744	0.63	Product	4042	1.15 to 1.70
SRT	1379	0.59	Misc.	1	
ERT	781	0.729			
FPN	43	0.711			
TEN	4494	0.709 to 0.711			
Misc.	21	0.69			
	15306			15299	
		FY-74			
ORGDP SHAFT	1373	0.37 to 0.55	Tails	10398	0.30
SRT	500	0.58	Product	3782	1.33 to 1.90
FPN	116	0.70	Misc.	1	
TEN	12204	0.709 to 0.711			
	14193			14181	

APPENDIX 1
(Continued)

SUMMARY OF FEEDS AND WITHDRAWALS - PADUCAH CASCADE

FY-53 THROUGH FY-76

Source	Feeds Quantity Tons U	Feeds Assay Wt. % ^{235}U	Withdrawals Type	Withdrawals Quantity Tons U	Withdrawals Assay Wt. % ^{235}U
		FY-75			
ORGDP SHAFT	703	0.529	Tails	10944	0.30
ERT	415	0.751	Product	4030	1.40 to 1.92
FPN	6477	0.709 to 0.712	Misc.	3	
TEN	7428	0.711			
	15023			14977	
		FY-76			
PDF	8873	0.30	Tails	17177	0.25
ORGDP SHAFT	757	0.32 to 0.53	Product	3772	1.5 to 1.9
ERT	958	0.77 to 0.82	Misc.	4	
FPN	2371	0.709 to 0.710			
TEN	8078	0.711			
Product	4	1.4			
	21041			20953	

PDF = Partially depleted feed which involves refeeding Paducah tails.

SHAFT = Slightly high assay feedable tails which may have originated at ORGDP, GAT, or the United Kingdom as designated.

HRT = Hanford reactor tails.

SRT = Savannah River reactor tails.

ERT = Enriched reactor tails (from Hanford but ^{235}U assay >0.711 wt. %)

FPN = Feed plant normal (Natural UF_6 produced in our Feed Plant).

TEN - Toll enrichment normal.

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APPENDIX 2

REACTOR TAILS AS PERCENT OF
TOTAL PADUCAH CASCADE FEED

FY	Type	% Reactor Tails
53	HRT	17
54	HRT	17
55	HRT	8
56	HRT	11
57	HRT	35
58	HRT	25
59	HRT	15
60	HRT and SRT	17
61	HRT and SRT	15
62	HRT and SRT	15
63	HRT and SRT	10
64	HRT and SRT	9
65		0
66		0
67		0
68		0
69	HRT	26
70	HRT and SRT	35
71		0
72	HRT	27
73	HRT, SRT, & ERT	65
74	SRT	4
75	ERT	3
76	ERT	5

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APPENDIX 3

DOMESTIC REACTOR TAILS FED TO ENRICHMENT CASCADES THROUGH FY-74

FY	HRT Quantity Tons U	HRT Assay Wt. % ^{235}U	SRT Quantity Tons U	SRT Assay Wt. % ^{235}U	ERT Quantity Tons U
		PGDP			
53	1565	0.66			
54	4104	0.67			
55	4066	0.66			
56	7383	0.67			
57	9674	0.66			
58	7653	0.65			
59	6193	0.65			
60	6292	0.64	25	0.60	
61	6205	0.64	12	0.60	
62	6713	0.63	265	0.60	
63	7293	0.64	452	0.60	
64	6025	0.63	978	0.60	
69	4781	0.64			
70	4518	0.64	11	0.59	
72	5283	0.64			
73	7744	0.63	1379	0.59	781*
74			500	0.58	
Subtotal	95492	0.64	3622	0.59	781
		ORGDP			
58	1596	0.69			
59	487	0.65			
60	1256	0.63	88	0.60	
61	242	0.62	932	0.59	
62			318	0.60	
70	392	0.64			
74	316	0.64			
Subtotal	4289	0.64	1338	0.60	
		GAT			
Subtotal	574	0.64	0		
Total	100355	0.64	4960	0.59	781

*Average ^{235}U assay = 0.73 wt. %.

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APPENDIX 4

NORMAL AND DOMESTIC REACTOR TAILS
FEEDS TO ENRICHMENT CASCADES
(THROUGH FY-74)

	Tons Uranium Fed			
Type	PGDP	ORGDP	GAT	Total
Normal	104859	34648	38441	177948
HRT	95492	4289	574	100355
SRT	3622	1338		4960
ERT	781			781

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APPENDIX 5

PADUCAH PLANT FEED
AND PRODUCTION FOR 24 YEARS
(FY 53 THROUGH FY 76)

Type	Tons U
Feeds	
PDF	384,458
ORGDP SHAFT	80,071
GAT SHAFT	60,363
UK SHAFT	1,102
HRT	95,492
SRT	3,622
ERT	2,154
FPN	64,993
TEN	64,220
Misc.	1,527
Total	758,002
Productions	
Tails (Includes those refed)	621,894
Product	124,718
Special (0.95 wt. %)	7,628
Special (0.71 wt. %)	1,886
Special (1.2 to 1.25 wt. %)	1,390
Misc.	144
Total	757,660

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APPENDIX 6

ENRICHMENT PLANT TAILS STOCKPILE
AS OF JUNE 30, 1975

Enrichment Plant	Quantity Tons U	Assay Wt. % ^{235}U
PGDP	161,414	0.2140
ORGDP	37,819	0.2276
GAT	35,501	0.2491
Total =	234,734	Weighted Avg. = 0.2215

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APPENDIX 7

NET ENRICHMENT PLANT TAILS
THROUGH JUNE 30, 1975*

Item	Quantity Tons U	Assay Wt. % ^{235}U
Stockpile	234,734	0.2215
Shipments	34,210	0.184
Discards	2,471	0.198
Total =	271,415	Weighted Avg. = 0.217

*Includes tails not refed to a cascade.

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APPENDIX 8

CALCULATED REACTOR ^{236}U PRODUCTION COMPARED TO MEASUREMENTS

A. Calculated

1. Thermal neutron cross section

σabs. for ^{235}U = 679 ± 3 barns
σf for ^{235}U = 580 ± 2 barns
σabs. for ^{234}U = 72 ± 10 barns
σabs. for ^{238}U = 2.76 ± 0.06 barns

2. For a rough approximation, the % of ^{238}U atoms converted to Pu is negligible compared to % of ^{235}U atoms fissioned and converted to ^{236}U (<1/2 of 1%).

3. The amount of ^{235}U produced by ^{234}U neutron capture is negligible. Approximately 11% as much ^{234}U is destroyed as ^{235}U (72 barns versus 679 barns). A ^{235}U burn-up from 0.711 to 0.64 constitutes about 10% loss in ^{235}U. The associated ^{234}U loss would be approximately 11% x 10% = 1.1%. Thus, the ^{234}U loss and corresponding ^{235}U gain (would be approximately (1.1% x 54 ppm = 0.6 ppm = 0.00006 wt. %).

4. Calculated ^{236}U Production
99/679 = 0.146 (Fraction of ^{235}U loss going to ^{236}U)

a. Burn-up to 0.64 wt. % -- 0.071 x 0.146 = 104 ppm (0.0104 wt. %).
b. Burn-up to 0.63 wt. % -- 0.081 x 0.146 = 118 ppm (0.0118 wt. %).
c. Burn-up to 0.60 wt. % -- 0.111 x 0.146 = 162 ppm (0.0162 wt. %).
d. Burn-up to 0.59 wt. % -- 0.121 x 0.146 = 177 ppm (0.0177 wt. %).

B. Measurements

1. Calculations are in good agreement with measurements made in FY-62 through FY-64 when HRT had a ^{235}U assay between 0.63 and 0.64 and a ^{236}U assay of about 110 ppm, while SRT had a ^{235}U assay between 0.59 and 0.60 and a ^{236}U assay of about 170 ppm.

2. Measurements on HRT and SRT in 1972 after some recycling through reactors gave ^{236}U measurements about 20% higher for the same ^{235}U assays.

3. Three measurements on enriched reactor tails fed to the PGDP cascade gave an average ^{236}U concentration of 412 ppm with a range of 270 to 680. Three other measurements on the material shipped to NLO gave an average ^{236}U concentration of 534 ppm with a range of 517 to 564.

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APPENDIX 9

TECHNETIUM RECEIVED IN REACTOR TAILS AND FED TO PADUCAH CASCADE

Stream	Quantity of Reactor Tails Tons U	Average Concentration ppm Tc, U Basis	Concentration Range ppm Tc, U Basis		Apparent ^{99}Tc Received kg
HRT and SRT	99,114	7	4 - 10		630
ERT	2,154	16	11 - 27		31
				Total	661

Fed to Cascade: (661-27)x0.85 = 539 kg.

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APPENDIX 10

NEPTUNIUM RECEIVED IN REACTOR TAILS AND FED TO PADUCAH CASCADE

Stream	Quantity of Reactor Tails Tons U	Average Concentration ppm Np, U Basis	Concentration Range, ppm Np, U Basis	Apparent Np Received kg
HRT and SRT before FY-67	74,898	0.24	0.01 to 0.6	16.3
HRT after FY-67	22,326	0.09	0.05 to 0.27	1.8
SRT after FY-67	1,890	0.12	<0.01 to 0.22	0.2
ERT	2,154	0.05	0.01 to 0.11	0.1
			Total	18.4

Fed to Cascade: 18.4 x 0.25 = 4.6 kg.

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APPENDIX 11

PLUTONIUM RECEIVED IN REACTOR TAILS AND FED TO PADUCAH CASCADE

Stream	Quantity of Reactor Tails Tons U	Average Concentration ppb Pu, U Basis	Concentration Range ppb Pu, U Basis	Apparent Pu Received Grams
HRT and SRT before FY-67	74,898	4*	2 to 6	272
HRT after FY-67	22,326	2.2	0.9 to 3.6	45
SRT after FY-67	1,890	1.0	0.2 to 2.5	2
ERT	2,154	4.5	3.1 to 9.0	9
			Total	328**

*Results were biased high since pulse height analyzer was not available to check extractions for alpha emitting impurities; however, the magnitude of bias is not known.

**Based on limited cascade dust measurements, it is estimated that about 0.1 gram of Pu was fed to the Paducah cascade (Pu alpha activity <0.2% that for Np).

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APPENDIX 12

ISOTOPIC AND RADIOCHEMICAL ANALYSES OF FRENCH REACTOR TAILS
(RECEIVED AT ORGDP IN CY-82)

Measurement	Feed Specification Level	Feed Specification Units	Avg.	Range
^{235}U	None	Wt. %	1.311	0.8683 to 2.487
^{236}U	None	Wt. %	0.24	0.015 to 0.39
^{234}U	None	Wt. %	0.016	0.008 to 0.019
^{233}U	500	ppm, ^{235}U basis	<400	<400
^{232}U	0.110	ppm, ^{235}U basis	0.055	<0.0005 to 0.079
Fission Product Gamma	20	% of Aged Natural U	<5	<5
Fission Product Beta	10	% of Aged Natural U	0.73	<0.1 to 1.2
Transuranic Alpha (Np & Pu)	1500	d/m/gU	6.1	<5 to 13
Tc	None	ppm, U basis	0.041	<0.005 to 0.10

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APPENDIX 13

MINOR ISOTOPES IN PGDP CASCADE PRODUCT AND TAILS

Cylinder Withdrawal Date	PGDP Product			PGDP Tails		
	^{234}U	^{235}U	^{236}U	^{234}U	^{235}U	^{236}U
10-2-55	0.0049	0.792	0.0100			
10-7-55				0.0006	0.175	0.0032
4-1-56				0.0005	0.143	0.0030
4-4-56	0.0041	0.714	0.0078			
April 57				0.0009	0.2501	0.0036
May 57				0.0010	0.2537	0.0033
June 57				0.0011	0.2571	0.0018
7-1-57	0.0101	1.096	0.0091	0.0014	0.234	0.0042
July 57				0.0010	0.2569	0.0027
Aug. 57				0.0010	0.2604	0.0027
Sept. 57				0.0010	0.2617	0.0028
Oct. 57				0.0010	0.2550	0.0028
Nov. 57				0.0011	0.2690	0.0028
Dec. 57				0.0012	0.2967	0.0024
Jan. 58				0.0013	0.3131	0.0021
Feb. 58				0.0014	0.3194	0.0026
March 58				0.0013	0.3105	0.0026
April 58				0.0014	0.3158	0.0024
May 58				0.0013	0.3131	0.0022
June 58				0.0014	0.3099	0.0024
July 58				0.0014	0.3196	0.0022
7-1-58	0.0112	1.3562	0.0064			
8-1-58	0.0110	1.3769	0.0028	0.0018	0.3141	0.0019
9-1-58	0.0130	1.4087	0.0054	0.0014	0.3391	0.0020
Sept. 58				0.0014	0.3175	0.0014
Oct. 58				0.0014	0.3170	0.0016
Oct. 59	0.0117	1.4539	0.0070	0.0014	0.3158	0.0018
11-1-59	0.0125	1.4550	0.0066	0.0016	0.3126	0.0022
Nov. 59				0.0014	0.3138	0.0020
Feb. 60				0.0014	0.3166	0.0030
Oct. 60				0.0014	0.3193	0.0026
5-1-61	0.0134	1.5822	0.0052	0.0018	0.3400	0.0020
Dec. 61	0.0126	1.5479	0.0066	0.0015	0.3431	0.0019
1-1-62	0.0123	1.5154	0.0064	0.0015	0.3331	0.0022
July 62				0.0014	0.3201	0.0025
Aug. 62				0.0014	0.3126	0.0022
Sept. 62				0.0014	0.3093	0.0024
Oct. 62				0.0015	0.3190	0.0016
Nov. 62				0.0013	0.3173	0.0022
Dec. 62				0.0015	0.3114	0.0026
Jan. 63*	0.0103	1.2494	0.0088	0.0014	0.3118	0.0021
2-1-63	0.0104	1.2491	0.0086	0.0014	0.3159	0.0021
Feb. 63				0.0014	0.3124	0.0022

APPENDIX 13 (Continued)

MINOR ISOTOPES IN PGDP CASCADE PRODUCT AND TAILS

Cylinder Withdrawal Date	PGDP Product			PGDP Tails		
	^{234}U	^{235}U	^{236}U	^{234}U	^{235}U	^{236}U
March 63				0.0015	0.3102	0.0024
April 63				0.0012	0.3044	0.0025
5-1-63	0.0104	1.2356	0.0089	0.0016	0.3054	0.0020
May 63				0.0014	0.3076	0.0021
June 63				0.0010	0.2718	0.0019
July 63				0.0012	0.3000	0.0020
Aug. 63				0.0014	0.3121	0.0026
Sept. 63				0.0014	0.3069	0.0026
Oct. 63				0.0014	0.3073	0.0025
Nov. 63				0.0013	0.3047	0.0026
Dec. 63				0.0013	0.3009	0.0019
Jan. 64				0.0013	0.2863	0.0022
2-1-64	0.0099	1.2506	0.0088	0.0013	0.2895	0.0024
Feb. 64*	0.0096	1.2507	0.0082	0.0014	0.2911	0.0025
March 64				0.0013	0.2883	0.0018
April 64				0.0012	0.2784	0.0028
May 64				0.0012	0.2767	0.0022
Aug. 64*	0.0050	0.9519	0.0046	0.0008	0.1978	0.0020
9-1-64	0.0048	0.9443	0.0042	0.0008	0.1955	0.0018
4-1-65	0.0050	0.9449	0.0042	0.0010	0.1970	0.0020
11-1-65	0.0056	0.9493	0.0084	0.0008	0.1996	0.0028
7-1-66	0.0055	0.9584	0.0080	0.0008	0.1963	0.0024
8-1-67	0.0055	0.9623	0.0068	0.0007	0.1978	0.0023
Oct. 68	0.0083	0.9836	0.0141			
12-31-68	0.0076	0.9823	0.0115	0.0010	0.1981	0.0036
6-30-69	0.0081	0.9833	0.0129	0.0008	0.1990	0.0030
12-31-69	0.0078	0.9826	0.0142	0.0009	0.1984	0.0045
6-30-70	0.0067	0.8913	0.0117	0.0008	0.2020	0.0020
12-31-70	0.0075	1.0521	0.0020	0.0008	0.2007	0.0005
6-30-71	0.0062	0.8910	0.0008	0.0008	0.2005	<0.0003
11-30-71	0.0102	1.3390	<0.0003			
12-6-71	0.0092	1.3409	0.0059			
12-7-71	0.0124	1.3436	0.0083			
12-14-71	0.0127	1.3404	0.0104			
12-21-71	0.0130	1.3398	0.0106			
12-28-71	0.0130	1.3404	0.0108			
12-31-71	0.0105	1.3495	0.0097	0.0014	0.3008	0.0018
1-4-72	0.0130	1.3896	0.0142			
1-11-72	0.0116	1.3975	0.0123			
1-18-72	0.0109	1.4055	0.0099			
1-25-72	0.0115	1.3954	0.0123			
2-1-72	0.0114	1.4048	0.0150			
2-8-72	0.0127	1.3989	0.0146			
2-15-72	0.0124	1.4006	0.0200			

APPENDIX 13 (Continued)

MINOR ISOTOPES IN PGDP CASCADE PRODUCT AND TAILS

Cylinder Withdrawal Date	PGDP Product			PGDP Tails		
	^{234}U	^{235}U	^{236}U	^{234}U	^{235}U	^{236}U
2-22-72	0.0120	1.4023	0.0171			
3-1-72	0.0111	1.3983	0.0073			
4-18-72	0.0127	1.3136	0.0161			
5-2-72	0.0125	1.3288	0.0167			
5-16-72	0.0117	1.3078	0.0123			
6-30-72	0.0114	1.3245	0.0127	0.0015	0.3000	0.0042
12-31-72	0.0153	1.7027	0.0292	0.0016	0.3002	0.0092
May 73*	0.0154	~1.6	0.0625			
Aug. 76	0.0139	~1.9	<0.0008			
Sept. 76	0.0157	~1.9	<0.0008			
Nov. 76	0.0159	~1.9	<0.0008			
Dec. 76	0.0163	~1.9	<0.0008			
Feb. 77	0.0151	~1.9	<0.0008			
12-31-77	0.0165	1.9506	0.0005	0.0013	0.2492	0.0004
6-30-78	0.0172	1.9353	<0.0004	0.0012	0.2504	<0.0004
12-31-78	0.0154	1.9498	0.0007	0.0008	0.2057	<0.0004
6-30-79	0.0104	1.3974	<0.0004	0.0007	0.2010	<0.0004
11-2-79	0.0104	1.4013	<0.0004			
11-5-79	0.0103	1.4076	0.0004			
12-31-79	0.0065	0.9498	<0.0004	0.0008	0.1996	<0.0004
6-30-80	0.0063	0.9504	0.0004	0.0009	0.1975	<0.0004
July 81	0.0062	0.9460	0.0003			
Oct. 81	0.0066	0.958	0.0001			
Nov. 81	0.0059	0.956	0.0015			
Jan. 82	0.0072	1.042	0.0008			
1-31-82	0.0077	1.1010	0.0006	0.0006	0.2008	0.0003
Feb 82*	0.0078	1.100	0.0004			
March 82				0.0008	0.203	0.0003
April 82	0.0079	1.101	0.0016			
May 82	0.0081	1.095	0.0012	0.0008	0.203	0.0018
June 82	0.0081	1.101	0.0034			
6-30-82	0.0080	1.1018	0.0028	0.0007	0.2019	0.0021
July 82				0.0008	0.204	0.0012
Aug. 82	0.0063	0.930	0.0007	0.0008	0.201	0.0008
Sept. 82	0.0058	0.947	0.0003	0.0007	0.202	0.0003
Oct. 82	0.0061	0.948	0.0006	0.0007	0.203	0.0003
Nov. 82	0.0064	0.951	0.0040	0.0007	0.206	0.0031
Dec. 82	0.0070	0.954	0.0010	0.0008	0.206	0.0006
12-31-82	0.0063	0.953	0.0003	0.0007	0.200	0.0002

*Average of two or three cylinders

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APPENDIX 14

^{99}Tc CONCENTRATIONS IN PGDP PRODUCT
(FY-72 THROUGH FY-82)

FY	Number of Measurements	Tc Concentration ppm, U Basis*	Concentration Range ppm, U Basis
72	5	0.67	0.19 to 1.7
73	13	4.5	<0.1 to 20
74	12	6.1	<0.2 to 20
75	12	1.0	<0.2 to 3
76	27	0.98	0.03 to 3.7
76A&77	35	0.71	0.02 to 6.3
78	20	0.19	0.02 to 0.97
79	24	0.14	<0.01 to 0.40
80	26	0.09	<0.01 to 0.38
81	16	0.025	<0.01 to 0.18
82	22	<0.01	<0.01 to 0.02

*In computing averages "less than measurements" were considered at half value.

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